2022

Isabelle Uslu

4/19/2022

Autonomous Cars

Image Recognition

A picture containing text

Description automatically generated

Contents

[**1.** **Introduction** 2](#_Toc101186276)

[**2.** **Process overview** 2](#_Toc101186277)

[**3.** **Industry/ Domain** 3](#_Toc101186278)

[**3.1.** **Market Snapshot** 3](#_Toc101186279)

[**3.2.** **Market Value** 4](#_Toc101186280)

[**3.3.** **Market Segmentation by Type** 5](#_Toc101186281)

[**3.4.** **Market Segmentation by Region** 6](#_Toc101186282)

[**3.5.** **Market Drivers** 7](#_Toc101186283)

[**4.** **How do autonomous cars work?** 7](#_Toc101186284)

[**5.** **Pros and Cons of autonomous cars** 8](#_Toc101186285)

[**6.** **Problem statement** 9](#_Toc101186286)

[**7.** **Stakeholders** 10](#_Toc101186287)

[**8.** **Business question** 10](#_Toc101186288)

[**9.** **Data question** 10](#_Toc101186289)

[**10.** **Data** 11](#_Toc101186290)

[**11.** **Data science process** 11](#_Toc101186291)

[**11.1.** **EDA’s** 11](#_Toc101186292)

[**11.3.** **Modelling** 11](#_Toc101186293)

[**11.4.** **Outcomes** 12](#_Toc101186294)

[**11.5.** **Implementation** 12](#_Toc101186295)

[**12.** **Data answer** 12](#_Toc101186296)

[**13.** **Business answer** 12](#_Toc101186297)

[**14.** **Response to stakeholders** 12](#_Toc101186298)

[**15.** **End-to-end solution** 13](#_Toc101186299)

[**16.** **References** 14](#_Toc101186300)

[**Project Documentation References** 14](#_Toc101186301)

[**Jupyter Notebook References** 14](#_Toc101186302)

**Capstone Project**

# **Introduction**

Autonomous cars – the concept has made a lot of hype over past eight to ten years. Though a lot has been going on this subject for as early as fifty years ago, studies have been done about how to make car learn by itself and then being able to drive on its own.

# **Process overview**

The following diagram shows the overall end-to-end process for defining, designing, and delivering the Capstone project.

Diagram

Description automatically generated

# **Industry/ Domain**

## **Market Snapshot**

* Industry/ domain is car industry.
* In 2021 the largest market by region was North America.
* Between 2018- 2027 compound annual growth rate (CAGR) is expected to be 22.75%. (Mordor Intelligence, n.d.)
* In 2021, 2.76 million units of autonomous cars were sold globally. \*

Graphical user interface

Description automatically generated

**\* Worldwide car sales in 2021: 59.6 million units**

## **Market Value**

The autonomous (driverless) car market was valued at USD 22.22 billion in 2021, and it is expected to reach USD 75.95 billion by 2027 while registering a CAGR of 22.75% during the forecast period 2022-2027. (Mordor Intelligence, n.d.)

Diagram, bar chart

Description automatically generated

## **Market Segmentation by Type**

The definitions for different autonomous levels in cars are given below:

➢ Level 1 - Driver Assistance  
➢ Level 2 - Partial Automation  
➢ Level 3 - Conditional Automation  
➢ Level 4 - High Automation  
➢ Level 5 - Full Automation

Timeline

Description automatically generated  
(NetApp, n.d.)

Following the SAE (Society of Automotive Engineers) International Automated Driving Standards, cars with Level 1-3 automation features have been considered in the market segment for semi-autonomous vehicles, Level 4 and 5 considered as fully-autonomous cars.

At present, Level 2 and Level 3 autonomous cars are most prominent in the market, while Level 4 and Level 5 (as scaled by SAE) are expected to reach wider acceptance by 2030. As a result, the growth of these Level 2 and Level 3 cars is expected to propel the market during the forecast period. (Mordor Intelligence, n.d.)

## **Market Segmentation by Region**

North America is expected to play a significant role in the market, followed by Asia-Pacific and Europe. Major automaker companies, technology giants, and specialist start-ups across North America have started investing in developing autonomous vehicle (AV) technology. As demand for self-driving cars is picking up across countries like China, Japan, India, and South Korea, the Asia-Pacific region is also expected to witness growth over the forecast period. (Mordor Intelligence, n.d.)

Map

Description automatically generated

## **Market Drivers**

Major players in the autonomous cars market are BMW Group, Tesla Inc., Ford Motor Company, General Motor Company, Nissan Motor Corporation, Daimler AG, Toyota Motor Corporation, Volkswagen AG, Volvo Group and Waymo LLC. (Cision PR Newswire, n.d.)

Graphical user interface, application

Description automatically generated

# **How do autonomous cars work?**

Autonomous cars rely on sensors, actuators, complex algorithms, machine learning systems, and powerful processors to execute software.

Autonomous cars create and maintain a map of their surroundings based on a variety of sensors situated in different parts of the vehicle. Radar sensors monitor the position of nearby vehicles. Video cameras detect traffic lights, read road signs, track other vehicles, and look for pedestrians. [Lidar (light detection and ranging)](https://www.synopsys.com/glossary/what-is-lidar.html) sensors bounce pulses of light off the car’s surroundings to measure distances, detect road edges, and identify lane markings. Ultrasonic sensors in the wheels detect curbs and other vehicles when parking.

Sophisticated software then processes all this sensory input, plots a path, and sends instructions to the car’s actuators, which control acceleration, braking, and steering. Hard-coded rules, obstacle avoidance algorithms, predictive modelling, and object recognition help the software follow traffic rules and navigate obstacles.

Diagram

Description automatically generated

# **Pros and Cons of autonomous cars**

Rise in the development of smart cities is a key factor driving the growth of the autonomous scars market. The electric autonomous cars help reduce air pollution in smart cities and also help to fight climate change. By using driverless cars, traffic accidents can be decreased by 90%, significantly improving the safety of our roads.

Below table shows some examples of pros and cons of autonomous cars.

Graphical user interface, text, application

Description automatically generated

# **Problem statement**

**Based on the below findings, “Social Acceptability” plays a major role on the sales of autonomous cars. Safety issues caused by technical errors is a major concern of the consumers and the public.**

Today we see a lot of experiments being done on driverless cars in a controlled environment under the supervision of human, and excellent road and environment conditions, but there are some challenges in designing a fully autonomous vehicle.

Even though machines usually do not make too many mistakes, there had been accidents with self-driving cars in the past. This is also because the technology behind self-driving cars is not mature yet. (Environmental Conscience, n.d.)

Diagram

Description automatically generated

A PCMag survey on future technology polled 2,016 people and included questions about [STEM toys](https://www.pcmag.com/article/368835/can-stem-toys-make-your-kid-a-computer-genius), [artificial intelligence](https://www.pcmag.com/news/368001/what-is-artificial-intelligence-ai), and driverless cars; 45 percent said safety concerns and technology failures were their biggest fears with autonomous vehicles.

Safety related issues decrease the social acceptance of autonomous cars, not only for the owners of these cars, safety is also a concern for the public who do not own or drive these cars.

There have been numerous high-profile accidents involving [Tesla’s current automated cars](https://www.bbc.co.uk/news/technology-51645566), as well as with [other automated and autonomous vehicles](https://www.theverge.com/2019/11/6/20951385/uber-self-driving-crash-death-reason-ntsb-dcouments). “[**Social acceptability**](https://theconversation.com/finding-trust-and-understanding-in-autonomous-technologies-70245)**”** is not just an issue for those wishing to buy a self-driving car, but also for others sharing the road with them. (The Conversation, n.d.)

In 2016, an 18-wheeler truck crossed a highway in Florida while a Tesla attempted to drive through it – at full speed. The Tesla driver as a result of injuries received. The car’s autopilot feature failed to brake because it could not distinguish the white side of the truck against the brightly lit sky. The National Highway Traffic Safety Administration determined that the occupant was at fault as they should have had an opportunity to brake before the collision but was likely distracted. (The National Law Review, n.d.)

Over time, the probability of accidents related to self-driving cars will decrease.

# **Stakeholders**

* Waymo – Google
* Cruise – General Motors
* Daimler – Mercedes
* Argo AI – Ford
* Aptiv
* Autopilot – Tesla
* Uber
* Traffic Jam Pilot – Volkswagen & Audi

# **Business question**

**“How can we increase social acceptability of autonomous cars to be able to attract more customers by improving the car’s safety?”**

* Stakeholders expect to increase sales and growth rates via increasing the safety of the car by solving the technical problems.

# **Data question**

**“How can we use machine learning and artificial intelligence to reduce / eliminate technical errors and improve autonomous cars’ safety?”**

Most autonomous vehicles will use artificial intelligence and [machine learning](https://iiot-world.com/artificial-intelligence-ml/machine-learning/machine-learning-algorithms-in-autonomous-driving) to process the data that comes from its sensors and to help make the decisions about its next actions. These algorithms will help identify the objects detected by the sensors and classify them, according to the system’s training, as a pedestrian, a streetlight, and so on. The car will then use this information to help decide whether the car needs to act, such as braking or swerving, to avoid a detected object.

In the future, machines will be able to do this detection and classification more efficiently than a human driver can. But now there is not widely accepted and agreed basis for ensuring that the machine learning algorithms used in the cars are safe. Autonomous car industry do not have agreement across the industry, or across standardisation bodies, on how machine learning should be trained, tested or validated. (The Conversation, n.d.)

# **Data**

* CIFAR10 dataset was used to demonstrate how different deep learning models perform on image recognition
* Data was sourced from <https://www.cs.toronto.edu/> and downloaded from Keras. Data was collected by Alex Krizhevsky, Vinod Nair, and Geoffrey Hinton.
* The CIFAR-10 dataset consists of 60000 32x32 colour images in 10 classes, with 6000 images per class. There are 50000 training images and 10000 test images.
* The test batch contains exactly 1000 randomly selected images from each class and the training batches contain exactly 5000 images from each class.
* Classes include; airplane, automobile, bird, cat, deer, dog, frog, horse, ship, truck.
* Dataset was used to be able to teach the models different type of vehicles that are on the roads as well as animals in different sizes.

# **Data science process**

## **EDA’s**

* Histograms are used to be able to demonstrate the quantities of each class in both train and test datasets.
* 1 image per class (10 image in total) are demonstrated in the EDA’s.
  1. **Data Pre-processing**
* Image normalization: all pixel values were divided by 255 to be able to normalize all values between 0 and 1.
* Target values were categorized.
* All images were augmented (rotated, shifted, zoomed etc) to be able to introduce noise to the dataset as objects can be in various positions and angles in real life.

## **Modelling**

* ResNet50, VGG16, DenseNet121 and traditional Conv2D’ s used to train and predict the images.
* Validation accuracy metrics were used to compare the models’ performance.
* The best model in terms of predicting images is Conv2D.
* Training the best model took 5 hour and 50 minutes as it was trained on computer’s CPU.

## **Outcomes**

* Conv2D model accuracy performed 79% predicting accuracy on the test set.
* This study showed that Conv2D model performed better on predicting images on test set.

## **Implementation**

* To be able achieve better results, models require to be trained on different classes such as traffic signs, road markings, pedestrians, traffic controllers/ police officers for body and sign language as well as different weather conditions such as fog, snow, heavy rain, and various accidents.
* Autonomous cars may require additional sensors especially for different weather and road conditions on different parts to be able to see objects in 360 degree and on different angles.
* Autonomous cars require powerful GPU’s to be able to detect objects as processing conditions take a lot of time.

# **Data answer**

* With a very small amount of data, winning model was able to predict images with 79% accuracy. This can be improved with more data.
* Different models can be used to predict on different scenarios such as road signs, road markings, objects etc.

# **Business answer**

* Once the model is trained with more data, image recognition related technical errors will reduce therefor car’s performance would become better and attract more consumers.

# **Response to stakeholders**

* Having simulators and more test vehicles on the road will increase the amount of the trainable data.
* With more trained data, cars will make more accurate decisions, and this will decrease the safety concerns related to technical errors. As a result, “social acceptance” will increase.
* For machine learning algorithms to learn trends, they require enormous amount of data. Collecting more data in different road and weather conditions is key to success.
* Cars require powerful GPU’s to be able to run the algorithms, make predictions and take actions.
* Going for partnerships with different stakeholders may be desirable to be able to take advantage of their expertise and reducing the costs.

# **End-to-end solution**

* Collect more data
* Train different models for different scenarios i.e., object identification, reading signs, detecting the state of stoplights, and other functions.
* Once the models are giving desired results, implement it on test vehicles
* Once the test vehicles giving desired outcomes implement it on production.

# **References**

# **Project Documentation References**

(n.d.). Retrieved from https://www.iiot-world.com/artificial-intelligence-ml/artificial-intelligence/five-challenges-in-designing-a-fully-autonomous-system-for-driverless-cars/

*Cision PR Newswire*. (n.d.). Retrieved from https://www.prnewswire.com/news-releases/global-autonomous-cars-semi--fully-market-report-2021-market-is-expected-to-reach-1-383-89-billion-in-2025---forecast-to-2030--301292821.html

*Environmental Conscience*. (n.d.). Retrieved from https://environmental-conscience.com/self-driving-cars-pros-cons/

*Mordor Intelligence*. (n.d.). Retrieved from https://www.mordorintelligence.com/industry-reports/autonomous-driverless-cars-market-potential-estimation

*NetApp*. (n.d.). Retrieved from https://www.netapp.com/blog/how-to-build-a-data-pipeline-for-autonomous-driving/

*The Conversation*. (n.d.). Retrieved from https://theconversation.com/autonomous-cars-five-reasons-they-still-arent-on-our-roads-143316

*The National Law Review*. (n.d.). Retrieved from https://www.natlawreview.com/article/dangers-driverless-cars

# **Jupyter Notebook References**

<https://www.kaggle.com/code/vivek468/very-basic-cifar-10-data-cnn>

<https://dev.mrdbourke.com/tensorflow-deep-learning/03_convolutional_neural_networks_in_tensorflow/>

<https://keras.io/api/applications/vgg/#vgg16-function>

<http://home.mit.bme.hu/~hadhazi/Oktatas/NN18/dem3/html_demo/CIFAR-10Demo.html>

<https://chroniclesofai.com/transfer-learning-with-keras-resnet-50/>

<https://www.youtube.com/watch?v=PIN9Bw6crMA>